Attaining Level 5 in CMM Process Maturity

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Abstract

In November 1998 the CSC SEAS Center achieved the rating of CMM Level 5 and became the sixth organization in the world to have ever attained that goal. The Capability Maturity Model (CMM) (Reference 1) is a worldwide recognized benchmark of process maturity for software organizations and is used to assess the quality of an organization's software process. During the period covered by this study, the SEAS Center comprised approximately 850 personnel supporting systems engineering, software development, and analysis for NASA/GSFC. During the years of continually improving the processes toward the goal of attaining the level 5 rating, detailed information was recorded, tracked and analyzed so that subsequent efforts by other CSC organizations could benefit from the experiences of SEAS. This paper is a direct result of the collection and analysis of that process experience data.

This paper begins with a brief overview of the SEAS organization that emphasizes the aggressive process improvement approach that has been in place since 1994. The paper will discuss the coordination of improvement initiatives, the role of goals and industry benchmarks, the organizational strategy and the use of key documents in measuring improvements. Additionally, the investment and benefits of an improvement program are discussed. Finally, based on the SEAS experience, the paper presents seven key factors that are the recommendations for any software organization undertaking an aggressive process improvement program.

Section 1 Background

CSC is a major software integration and services provider with over 50,000 employees in offices worldwide. The Systems, Engineering, and Analysis Support (SEAS) Center is part of the Federal Sector and comprises approximately 850 persons supporting the National Aeronautics and Space Administration (NASA) at the Goddard Space Flight Center (GSFC) in the disciplines of systems engineering, development, maintenance, and analysis (Figure 1-1).

CSC has supported NASA in the GSFC environment since the 1970's. Staffing at the Center has varied from 700 to 1700 over the last 10 years. The SEAS Center is organized as a program with central offices supporting program management (PMO), process engineering (PEO), quality assurance (QAO), and program control (PCO). Software configuration management is typically a project responsibility and subcontracting for product development is very rare. The number of projects within the program varies but is typically about 20. Approximately 50% of the organization is directly involved in the software development or maintenance activity.

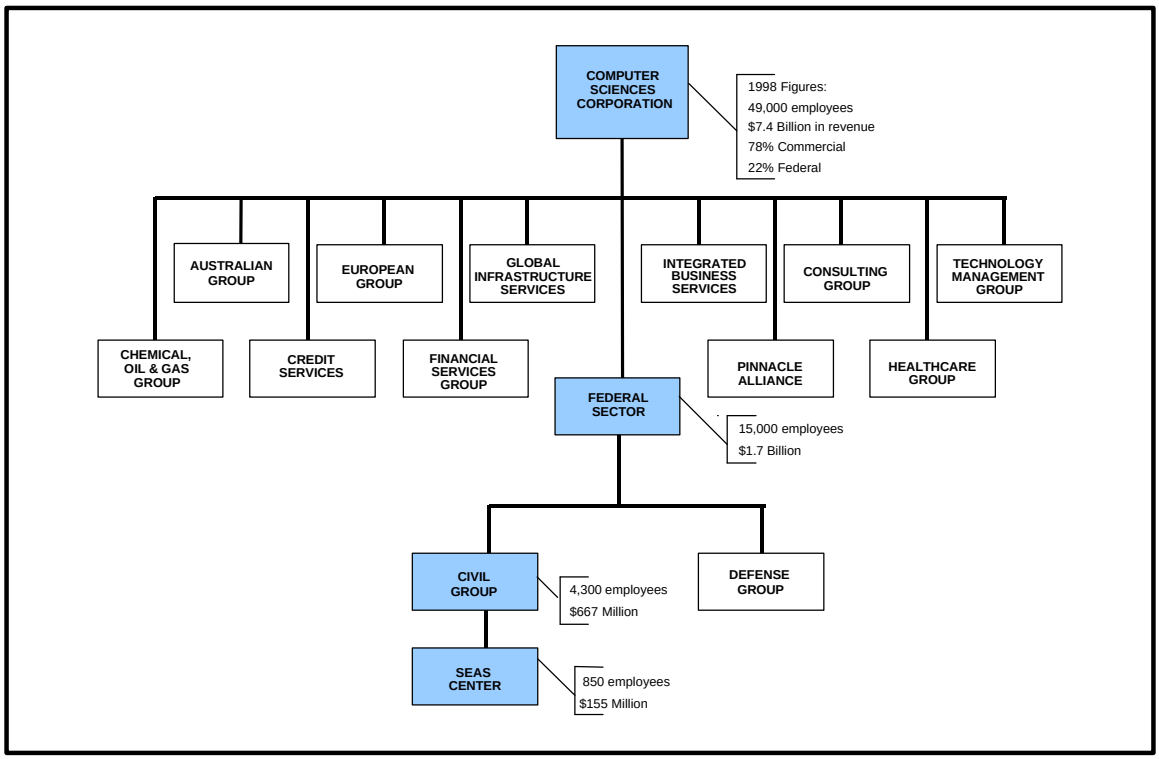

Figure 1-1 SEAS Center Within CSC

Because of the growing importance of establishing process maturity within software intensive organizations, the SEAS Center initiated an aggressive process improvement program in 1995. A process improvement plan with specific goals was written to guide the initiative. Of the goals, four were product goals with objective measures

(productivity, quality, predictability, cycle time), and another goal specified compliance with standard industry benchmarks.

The processes used to support the work on SEAS have always been regarded (by the CSC staff) as being good processes although an early external evaluation of the processes produced a Level 1 CMM rating in 1991. Despite this early discouraging result, the Center continues to view benchmark evaluations as an important activity supporting process improvement efforts (Figure 1-2).

After some success with internal process audits and CMM self-assessments, SEAS Center adopted the use of evaluations against industry benchmarks conducted by independent consultants. The 1995 process improvement plan included goals for both CMM and ISO 9001 (hereafter referred to as ISO) evaluations.

The results of benchmarking activities are summarized in Table 1-1. In 1998, the SEAS Center became the sixth organization in the world to be rated at CMM Level 5 and the first organization to be both CMM Level 5 and ISO registered.

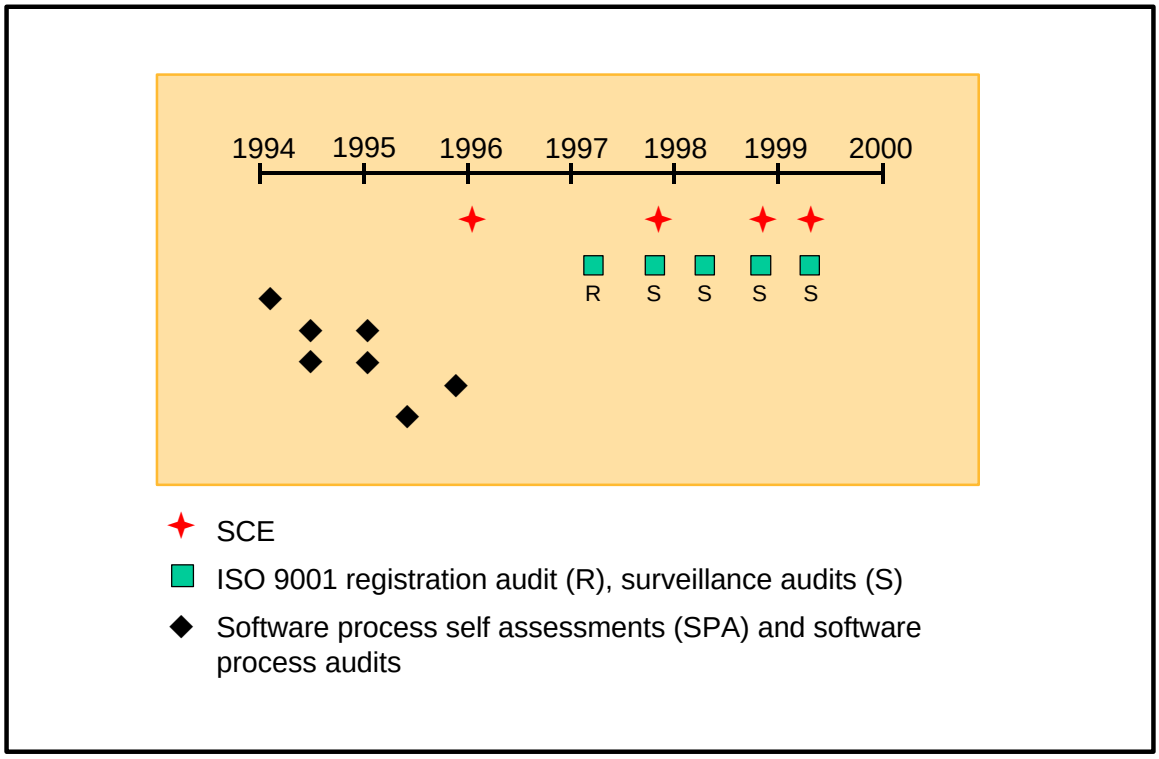

Figure 1-2 SEAS Center Benchmarking History

	SCE (2/96)	ISO (5/97)	SCE (11/97-1/98)	ISO (11/97)	ISO* (6/98)	SCE (11/98)	Part of 'Group' SCE (5/99)
Preparation time	• 4 months	• 12 months	• 2 months	• 6 months	• 1 month	• 4 months	• 1 month
Organization effort	• 1800 staff hours	• 3400 staff hours	• 800 staff hours	• 500 staff hours	• 200 staff hours	• 800 staff hours	• 60 staff hours
Use of external consultants and training	• None	• 200 hours - Consultant - Internal auditor training - Pre-registration assessment	• None	• None	• None	• 2 staff days	• None
Preparation strategy	• Perform gap analysis • Use lessons learned from 1991 SCE • Focus on deployment	• Develop implementation plan • Use external experts • Train staff • Focus on deployment	• Complete actions items • Provide awareness seminars • Use internal assessments	• Continue process improvement initiatives • Focus on management review, internal audits, and corrective actions	• 1 refresher lecture • Internal audits continued	• Study/learn specific details of level 4-5 • Advance collection of evidence • Group seminars • Mock SCEs	• Update 'evidence' archives • Group seminars
Results	• 13 of 18 KPAs satisfied	• ISO registration achieved	• CMM Level 3 achieved Levels 4-5 (2 of 5 KPAs satisfied)	• ISO registration maintained (2 minor findings)	• ISO registration maintained (3 minor findings)	• CMM Level 5 achieved (18 of 18 KPAs)	• All reviewed KPAs satisfied

* Additional ISO assessments held in 11/98, 5/98, and 11/98

Table 1-1 Summary of Benchmarking Activities

Section 2 Approach

As discussed in Section 1, SEAS had an extensive legacy of process development and improvement at the time that it achieved CMM Level 5 in 1998. SEAS process development work during the late 1980s and early 1990s consisted primarily of refinements of the SEAS System Development Methodology (SSDM) and its supporting standards and procedures (S&Ps). Such refinements were recommended by process users and approved by senior management. This bottom-up approach worked reasonably well and resulted in the establishment, deployment and use of SSDM and approximately 100 S&Ps.

Between 1989 and 1994, 508 proposed changes to SSDM were submitted by process users; of these, 379 were implemented in whole or in part. Unfortunately, most concerned relatively minor adjustments to existing processes. SEAS management noted three major flaws in this process improvement strategy: (1) a formal "learning through experimentation" process was not being used, (2) establishment and measurement of goal achievement was weak, and (3) SSDM and its associated S&Ps were becoming obsolete since new approaches and methods were not being adequately integrated. A new approach was needed.

During the early 1990's the Quality Improvement Paradigm (QIP) (Reference 2) was being used in the SEAS Software Engineering Laboratory (SEL). (The SEL, Reference 3, is a joint venture involving CSC, NASA and the University of Maryland.) The QIP, shown in Figure 2-1, established a framework for improving SEAS by treating projects as experiments, packaging results, and making such results available to all SEAS projects. The QIP eliminated the process improvement flaws noted above and was accepted by SEAS management as a solid foundation upon which to build the SEAS improvement program. Since 1994 the QIP has served as the model for process improvement for the SEAS Center.

The SEAS adoption of the QIP as its improvement model focused attention on improving key activities such as communication, coordination, establishment of goals, measurement of change, and experience sharing. Thus, attention was redirected from refinement of existing processes to making SEAS a learning organization based on the experiences of its projects. Adoption of the QIP radically changed how improvement was addressed by the organization. Some of these changes are briefly discussed below.

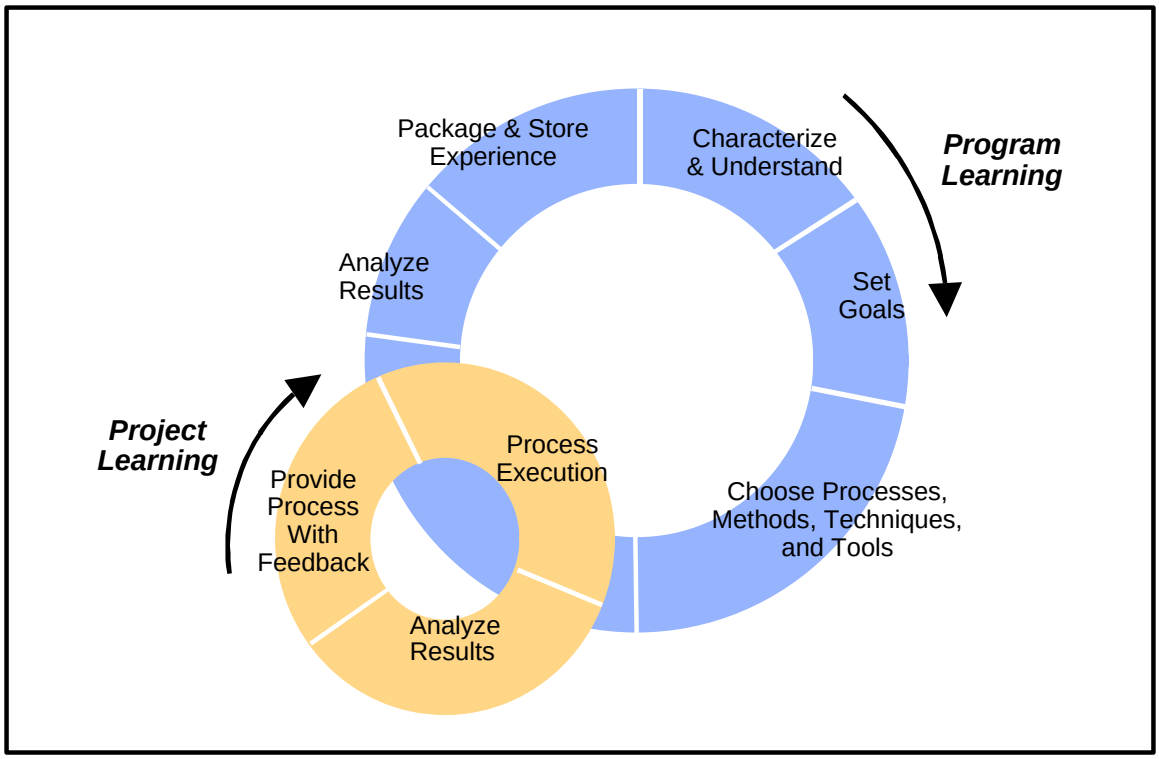

Figure 2-1 Quality Improvement Paradigm (QIP)

1. SEAS-Level Coordination of Projects' Process Improvement Initiatives.

The QIP is based upon the assumption that a Program-level group is aware of project-level experiments, provides guidance to projects, and makes successes and failures known to other projects within the Program. For SEAS, responsibility for this type of coordination was assigned to the PEO. Use of "shepherds" and weekly 'Process Deployment Team Meetings' as described below directly resulted from adoption of the QIP.

- Shepherds are typically Process Engineers or Quality Assurance personnel who are aware of activities and project experiments throughout the organization. The shepherds are assigned to work directly with a project to guide process implementation and avoidance of problems experienced by prior projects. The shepherds perform as project support personnel in responding to needs of the projects in tailoring, understanding, and implementing processes appropriate for the project.
- Process Deployment Team Meetings are weekly 1-hour meetings held to discuss some aspect of the SEAS processes. The meetings are facilitated by a process engineer and attended by all levels of management and some personnel from the projects. Typically, these meetings take the form of a briefing followed by questions, answers and comments regarding the given topic. Topics have included; top 10 steps in adopting mature processes, effective use of measurement, how ISO and CMM are related, impacts of inspection techniques for software, how to set goals in project planning, effective risk management, how our processes conform to Level 5, and

results of recent project experiments presented by project personnel. The meetings are interactive, with all participants joining in the discussion.

2. Establishment of Product-related Goals Rather than a Goal of Compliance with Industry Benchmarks

The QIP requires establishment of goals. For organizations such as SEAS, compliance with industry benchmarks is an important business goal. Much of SEAS process-related work in the early 1990s was directed to the goal of demonstrating compliance with the CMM. However, once the QIP had been adopted as the improvement model, SEAS goals evolved from a focus on complying with industry benchmarks to a focus on improving products and achieving customer satisfaction. Project buy-in to use of the QIP was easily achieved once projects appreciated the value of learning to improve their products based on the experiences of prior projects.

3. Use of Industry Benchmarks as Tools to Achieve Product-Related Goals

SEAS established ISO-9001 as its primary tool for guiding and measuring improvement. Similarly, the SEI CMM served as a tool for measuring progress in improving the SEAS software development processes. ISO requires participation by all elements of the organization, in contrast to the software development focus of the CMM. However, ISO-9001 and the CMM are complementary and support the product improvement strategy as embodied in the QIP. (As a byproduct, use of ISO and CMM support senior management's business goal of compliance with key industry benchmarks.) Industry benchmarks such as ISO and the CMM served as gates for verifying process maturity and use. Use of external assessors ensured objectivity in measuring progress toward achievement of goals related to compliance with industry benchmarks.

4. Use of 'Separation of Concerns' Strategy

Project personnel were not required to become familiar with the details of the QIP or industry benchmarks; deployment of the QIP, ISO, CMM and other strategies was assigned to the process engineers. This left projects free to focus their limited resources on improving their products and services rather than on complying with industry benchmarks. As discussed above, the shepherds provided guidance to projects in applying the QIP and complying with the industry benchmarks.

5. Document Organization Profile and Improvement Goals

Application of the QIP requires an understanding of current product characteristics (defect rates, cycle time, accuracy of estimates, etc.) and improvement goals. Therefore, consistent with the QIP, SEAS documented its organizational and product characteristics in a profile document (Reference 4) and established SEAS-level improvement goals in a process improvement plan (Reference 5). These documented "where we are" and "where we want to go", and served as the roadmap for measurable process improvement. The SEAS Quality Management System Manual (Reference 6) documented the roles and responsibilities of each SEAS group in achieving improvement.

The reader should be cautioned that the QIP worked well for SEAS and would likely work well for other organizations. However, for maximum effectiveness, it should be applied with consideration given to the culture and maturity of the organization. For SEAS the approach was to focus on identification and deployment of a formal model since basic processes were already in place. Recommendations for other organizations are provided in Section 4.

Section 3 Return on Investment

In order to determine the value of investment made toward process improvement, the SEAS Center measured impacts of improvements in three areas: 1) impacts to the performance of the organization 2) impacts to business opportunities and 3) impacts to the products generated. This set of measures of 'return on investment' was used to continually mold the program of process improvement and to help determine which areas of improvement should be the focus for continued efforts. They were also used to make a determination as to whether or not the process improvement program was worth the investment of time and resources and whether or not the program should be continued or modified. The value of the process program was measured against the cost of the overall program. This value of the program compared to the investment cost is what we term 'return on investment'.

3.1 Cost of Process Improvement

The cost of the process program was tracked by maintaining detailed records of the effort expended by staff carrying out activities directly on the program (Process Engineering staff as well as Quality Assurance staff) and also including indirect effort required by the project organization in attending special training sessions or attending special audit activities. The tracked costs include developing processes, deploying, measuring, training, maintaining (packaging), developing infrastructure, and process improvement. The costs do not include project operations performing CM, QA, planning, etc., but do include their cost of participating in studies, training, audit participation.

For the period July 1994 through November 1998 (the date when the Level 5 was attained) the cost of the process improvement program was approximately 30 staff years of effort. This cost was primarily the cost of the organization's process engineers responsible for defining and carrying out the improvement program. Fairly detailed records were kept in order to track this expenditure. Records of costs permitted the analysis of the distribution of effort across different functions and the shift of allocation from early months of the program to later months of the program.

The records of costs categorized the effort by 5 main areas of activity: (1) writing and maintaining written processes, (2) deployment of processes (working with projects via training and direct help in using processes), (3) creating and maintaining the infrastructure of processes (data bases, libraries, etc.), (4) planning improvement including the writing of plans, carrying out studies and analyzing measurement, and (5) reporting and participating in reviews of the process program.

Table 3-1 shows the distribution of the effort for these 5 major activities. Overall, the highest percentage of effort was allocated to the deployment activities. Process engineers focused on getting the defined processes into practice (shepherding) as opposed to only focusing on generating and maintaining the written standards, processes, methodology, etc.

Activity	4 year cost	1995-1996	1997-1998
Develop/Maintain Processes (write/update)	6 SY	40%	15%
Deploy/Training/Awareness	10 SY	10%	40%
Infrastructure (data base, libraries, distribution)	2 SY	5%	5%
Process Improvement (planning, studies, experiments, analyzing)	8 SY	15%	30%
Assessment Preparation (SCE, ISO)	3 SY	25%	5% - 5%
Reporting/Reviews	1 SY	3%	3%

Table 3.1 Cost Distribution for Process (For Organization of 800 Persons Over 4 Years)

Table 3-1 also indicates a shift in emphasis from the writing and refining written processes to the emphasis on deployment of process. The shift reflects that over time the process engineers realized that the largest value of the program was in interacting directly with the projects and not in merely producing and enhancing written processes.

3.2 Value of the Process Improvement

As mentioned in the introduction, the impact of the process program was measured in three areas: value to the organization, value to business opportunities, value to the products generated.

3.2.1 Impact to the performance of the organization

The first measure of the impacts of the improvement program was a determination of perceptions, general performance and structure of the organization as a whole. In general, it is a determination as to whether or not the personnel viewed the program and the changes as a value to their own projects performance. This was determined by taking surveys, interviewing project personnel and managers and by soliciting feedback from customers.

There were significant favorable impacts to the overall enterprise characteristics of the SEAS organization. These changes included both technology enhancements as well as operational impacts that supported a more efficient and effective structure. Specific

impacts that were identified by both project personnel as well as managers across the organization included:

1. The process improvement program resulted in a focus of achieving common goals for SEAS. With the formal improvement plan generated and with specific goals identified as part of the plan, there was a foundation established for all SEAS personnel to contribute to improvement. The improvement goals and overall program prompted project personnel to contribute to the overall SEAS improvement program as opposed to only their own project program. This was supported through the management reviews, process meetings, progress reporting and assessments (both internal and external) that were included as part of the program. The improvement program promoted the concept of SEAS operating as a well disciplined enterprise rather than a set of individual projects with local goals and challenges only.

   This fact of operating as an integrated organization also improved the communication between projects (sharing lessons, improvement ideas, measurement approaches, and tailoring approaches for SEAS processes).

2. The improvement program added a strong discipline for all projects to adopt and adhere to SEAS processes. The improvement program included the use of formal assessments such as ISO audits, SCEs, and internal audits. With the use of regular formal assessments and with the strong senior management support of the improvement program, all projects within SEAS had strong incentives to adhere to the processes and disciplines defined by SEAS.

3. The improvement program resulted in a significant upgrade and improvement to the set of SEAS standards, policies, and processes. Since the program adhered to the concept that changed processes should be driven by needs and experiences of projects (as opposed to being changed to meet an external benchmark) and since ISO stressed the value of producing processes that were short, crisp and directed to the actual needs of the projects, the set of SEAS standards and processes were revised with a focus on project need and SEAS lessons learned. This resulted in a set of processes that the projects felt were much more in keeping with their specific needs.

4. The improvement program promoted an accelerated adoption of needed technology change. The activities of the improvement program included the continual search and incorporation of enhancements that would lead to more efficient development and operations. There were several technology changes that were driven by this approach to sustain change. Such enhancements as the universal adoption of on-line, electronic documentation and the adoption of common CM tools were prompted by the improvement program. The goal of attaining full ISO registration was more easily addressed by producing complete on-line, electronic documentation.

5. The accomplishments resulting from the improvement program produced a sense of pride and accomplishment for the entire SEAS organization. The recognition that SEAS received by achieving ISO registration and by attaining high maturity ratings with CMM was shared by all SEAS personnel. Since all projects and personnel participated at some level, the entire organization felt the recognition received was something that each of the individuals could be proud.

3.2.2 Impact to business opportunities

The second measure of value of the process improvement program is the impacts it had on business opportunities. The improvements demonstrated by the SEAS program played a major role in winning new business for CSC. The improvement program in general demonstrated to potential clients that CSC was very serious and committed to process improvement. This fact alone can be a discriminator in selecting a support contractor. It is important that clients see a demonstrated program of sustained improvement.

In addition to demonstrating an aggressive improvement program, CSC could point to the levels of achievement recognized by CMM and by ISO. These achievements are frequently used by potential clients in scoring capabilities of contractors. In the case of the SEAS achievements, at least 3 programs used the independent ratings (ISO and CMM) and the established processes as consideration in selecting CSC for additional work. The additional work in 1999-2000 amounted to over $500M in contract value. The established SEAS processes were identified as key elements of the new work.

3.2.3 Impact to the software products

Probably the most important measure of success of any improvement program is the measure of product improvement. Have the products and services been favorably impacted by the changes made to process?

The SEAS improvement plan identified 4 product measures that were part of the goals of improvement. The product measures included productivity, defect rates, cycle time, and estimation accuracy. From the start of the program in the Summer of 1994, detailed measures, records, and general information were recorded for the purpose of guiding the change and for tracking impact of any changes that were made. Details of the measures that were tracked and the results of analyzing the changes to the product measures were reported in 1998 at the time of the Level 5 rating. Details of these results can be found in Reference 7.

By reviewing the detailed process ratings over many years along with the detailed product data (productivity, defect rates, etc.) an attempt was made to statistically determine the correlation between the process changes (increasing maturity level) and the product changes. The analysis showed a constant 6 percent/year improvement for both productivity and quality from the start of the program through the end of 1998. (See Figure 3-1). Further analysis showed that there was also a 6 percent/year improvement from 1987 through 1994. Attributing sustained product improvement to process change from this evidence is not conclusive. Improvements in technology, personnel, environments, as well as process change, remain as possible sources of the observed product improvements.

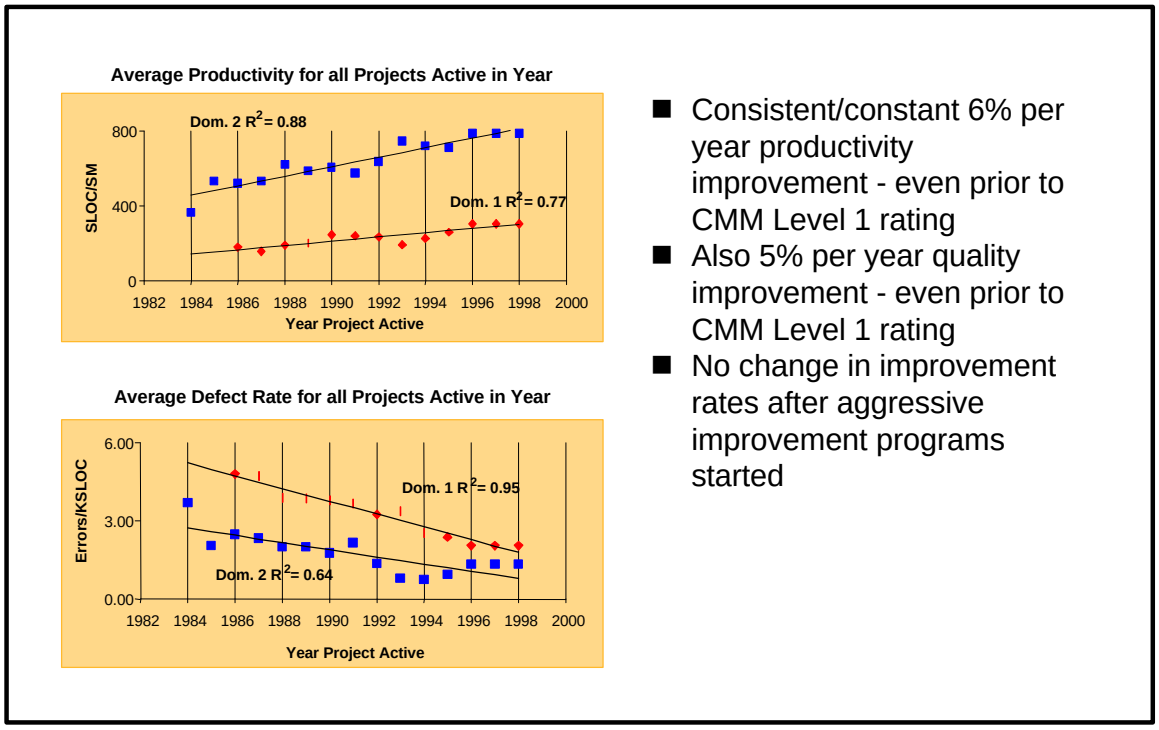

Figure 3-1 Productivity and Quality Trends Over Time

When an attempt was made to correlate process maturity of projects with the product measures (Figure 3-2) there was no statistically significant result. The correlation was computed from data extracted from SCE reports generated for each project. Each project was reported compliant, partially compliant or not compliant with each Level 2 and 3 Key Process Area (KPA). From this data, each project was assigned a maturity 'score' on a scale from 1 to 3. Product measures and the maturity 'score' were analyzed for a correlation between high maturity ratings and the high performance of each of the product measures (quality, productivity, cycle time and predictability). Correlalations were all of low significance; the R^2 values ranged from a low of 0.15 to a high of 0.49. There is not a clear explanation for this, but the authors surmise that the strongest explanation is that process is simply a very difficult parameter to measure in isolation. Using a project's maturity rating as the only measure of process may be too simplistic. Details of this process are explained in much more detail in Reference 7. Work on this analysis is continuing.

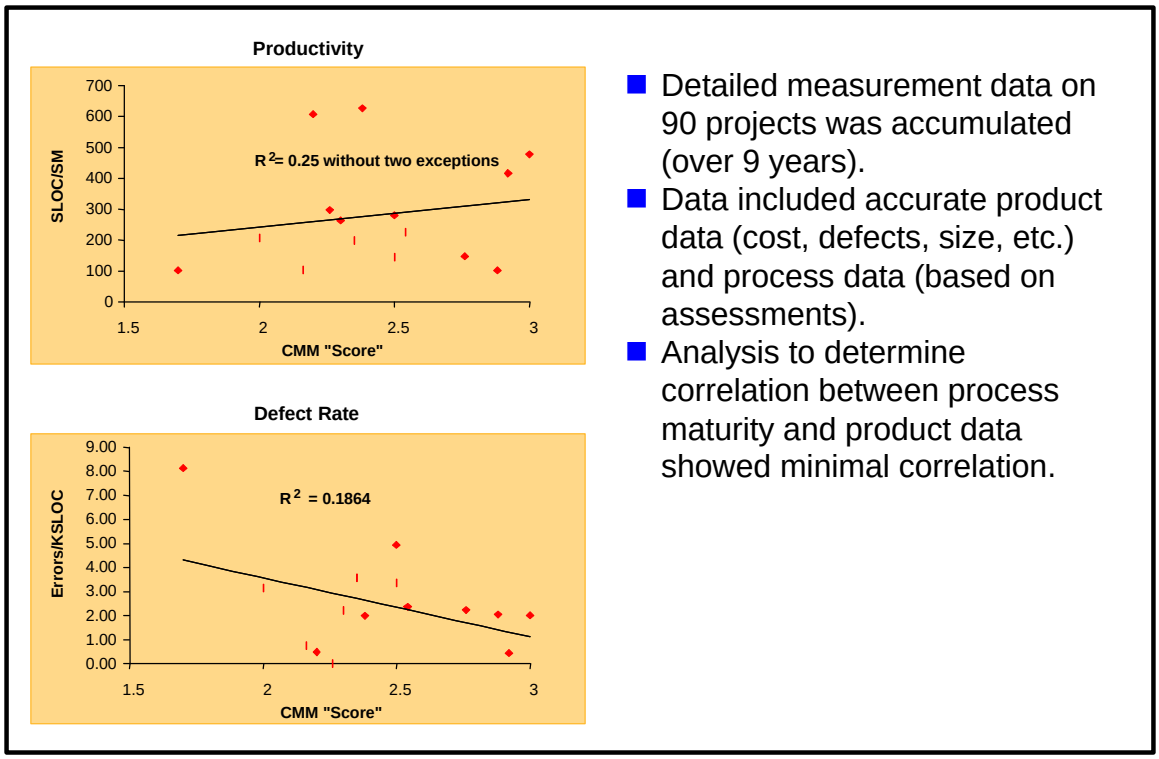

Figure 3.2 Impact of CMM Maturity on Cost, Quality, Manageability

3.3 Relative Impact of Improvement Activities

There were many activities undertaken and many avenues pursued with the goal of attaining the high maturity ratings and demonstrating improvements to the SEAS organization. Shortly after the Level 5 rating was achieved, a review of the lessons, activities and steps was held in an attempt to determine which of the steps seemed to be of most significant value (and which seemed to be of minimal value).

Sources of information included surveys collected from project developers and managers, lessons learned reports generated periodically during the 4-year initiative, interactive workshops held (as part of the regular 'Process Deployment Team Meetings'), and interactive discussions held with the process and quality assurance personnel. Personnel were asked to identify which activities had the most favorable impact on improving processes within SEAS as a whole and on projects specifically. Four activities consistently were rated as being the most effective in leading to the success of the process improvement:

- Shepherding
- Process deployment team meetings
- Library building with process evidence
- ISO

The first two activities were discussed in detail in Section 2.

The evidence gathering/library building was an exercise requiring projects to produce specific evidence for key aspects of project processes. There were several benefits to this exercise:

- It allowed the process engineers to review evidence and point out potential deficiencies (so projects could make adjustments)
- It disciplined the projects into reviewing just how processes were being implemented.
- It enabled the sharing of concepts across projects through the sharing of artifacts and the discussion of approaches at process deployment team meetings.
- It helped to identify processes that may be misused or ineffective.

ISO was almost universally identified as one of the most beneficial tools adopted in pursuing excellence in process within SEAS. Although CMM had been part of the culture within the organization for over 7 years, the use of ISO was identified as one of the top activities in attaining excellence. Several reasons were given for this:

1. ISO addressed the entire SEAS organization as opposed to software projects and personnel only. This required that all personnel be involved in the concept of process which resulted in SEAS becoming a fully integrated enterprise with process as a major theme.
2. ISO was much easier to understand and to adopt than the full suite of CMM KPAs. It de-emphasizes process detail and focuses on understanding and applying the basics.
3. ISO successes gave the organization a ‘can-do’ attitude which was reflected in a much higher level of confidence when more detailed reviews of CMM were addressed.

Section 4 Lessons Learned

As was noted previously, detailed records of the experiences, costs, impacts and general impressions of the overall activities were archived by the process improvement team. In reviewing this information and by carrying out extensive interviews with project personnel and managers, the successes and shortcomings were analyzed in an attempt to identify the most effective activities and approaches that led to the high maturity level of the SEAS Center. There are 7 points that were gleaned from the experiences as reflecting the most important activities that an organization should adopt as part of their improvement program.

Recommendation 1: Operate as a Level 5 Organization

This recommendation suggests that an organization should not focus on sequentially addressing the CMM Levels from 2 through 5 nor should they focus on sequentially addressing individual KPAs. Instead, the most important element of the improvement program is to establish a culture of continuous improvement based on the goals and needs of that organization. The concept of 'continuous improvement' can be termed an 'optimizing' organization (Level 5) and has several key elements that should be established from the start:

- Focus on improvement of the product (as opposed to merely improving process). Such goals as cutting defects or improving productivity or decreasing cycle time should be the measure of change; not the number of processes that are established.
- Step 1 is to define the baseline of the products and process. That implies that the current product characteristics (cost, time, defect rates, effort distribution, etc.) must be captured along with the baseline of process characteristics (extent to which KPAs are satisfied). In addition to establishing the existing strengths and deficiencies of processes (via process gap analysis) one must generate a baseline or profile of the product characteristics. This information is the first step toward producing quantifiable information of the environment and is used to track impacts of process changes as well as to produce engineering models of the environment. Information for this baseline is collected from existing measurement data, surveys, project archives, interviews, and any other source of data that may provide some insight into the overall product profile.
- A measurement program is a requirement at the start of the overall improvement program. Some models imply that a mature measurement program may not be a critical element of early stages of an improvement effort, but the concept of operating as a Level 5 requires that a measurement program be established immediately. The measurement program is required for 3 specific reasons: (1) to establish models of the environment, (2) to manage projects, and (3) to guide change. An example of basic models generated early in the improvement program is depicted in Figure 4-1 The early data from SEAS was used to produce these models which in turn are used by managers and by process engineers. Such models can be generated very early in the

program and then may be continually refined as improved measurement data is collected.

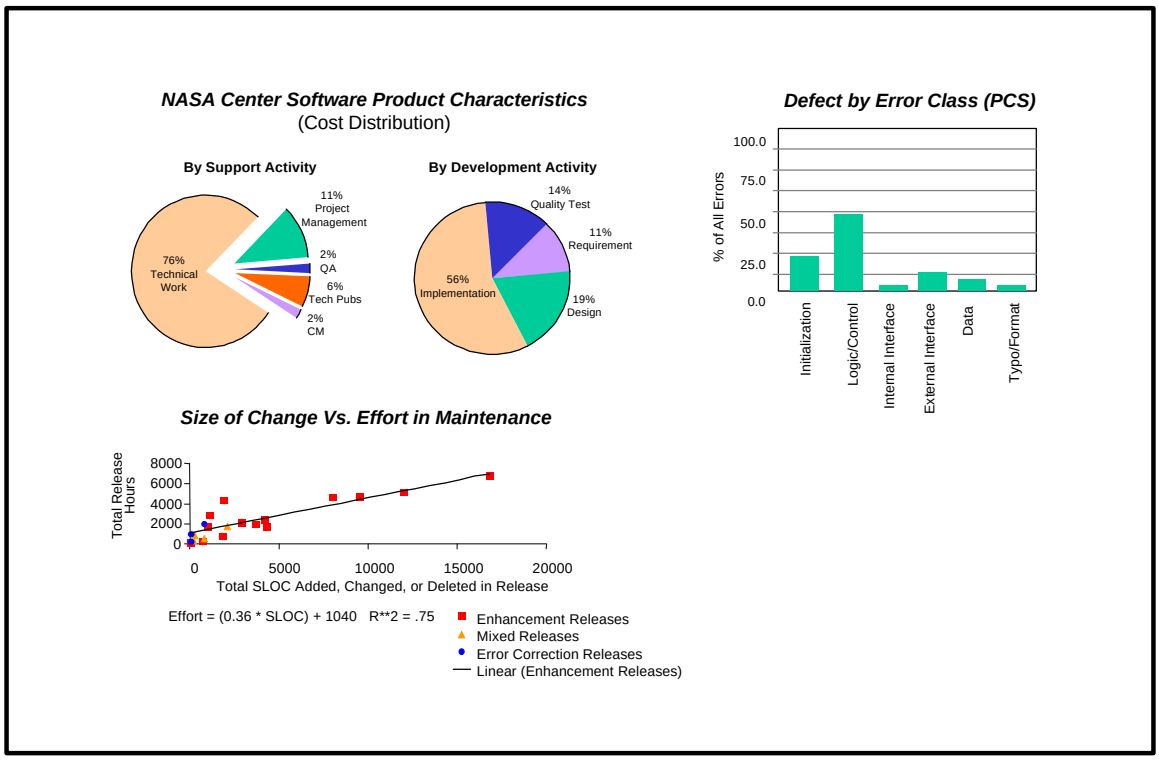

Figure 4.1 Sample Engineering Models of Process

- Both technical and management activities should be part of the improvement activity- as opposed to management only. Not only are process attributes important to the improvement program, but the selection and understanding of changing technical activities must be integrated into the program. This implies the continual infusion, tailoring and measuring of technical changes.

Recommendation 2: Set Specific Incremental Gates

Although the improvement program is viewed as a continuous, sustained program that has no completion criteria, incremental check points for the organization were a tool that accelerated the improvement efforts and acted as a catalyst for the program. These check points were most effective when they were performed by external reviewers; specifically SCE teams or ISO teams.

In the period June 1994 through November 1998, seven independent reviews were conducted. Obviously one has to be cautious of overtaxing the development and project organizations by requiring excessive time in participating in reviews, but the periodic reviews do act as a vital tool in assuring that all personnel are reviewing their adherence to processes and their awareness of the overall plans and goals of the organization.

Internal audits should be part of any organization's process program, but they do not replace the value of the reviews carried out by an independent, external team.

For the SEAS organization (about 850 persons) there were formal reviews occurring approximately every 6 months, sometimes more frequently. ISO surveillance audits occur each 6 months and the external CMM assessments occurred approximately yearly.

Recommendation 3: Adopt the Concept of 'Separation of Concerns'

Another critical element of a successful improvement program is that of organization. Not only must there be strong support from senior management, but there must be a designated process improvement organization whose responsibilities include expertise in process models, CMM, ISO, process improvement concepts, measurement and available assets within the organization. With one organization focusing on the concepts of process improvement and focusing on the generation of Program-level assets to be used by projects, then projects can focus on the task of producing systems and software.

In an 'Experience Factory' (Reference 8), one organization (PEO) is responsible for driving process improvement while the other organizations (projects) focus on the task of producing a quality product. It is not necessary that a project organization become expert in process models; it is only necessary that they work with the process organization in sharing information and adopting processes and assets made available to them.

The 'separation of concerns' concept implies that the project personnel are experts in producing systems and the process organizations are experts in process improvement and associated activities. There is no need to train project personnel in the details of process models such as CMM or ISO, it is only necessary they understand, and apply the process assets provided by the process organization.

Recommendation 4: Deploy Processes to Projects

One of the most effective steps in attaining process maturity was found to be that of having the process engineers work directly with the projects in helping to define, apply and understand appropriate processes for their particular project. This activity is in contrast to that of having the process staff work on writing, refining, tailoring, enhancing written processes. The effort put forth in working directly with projects will be much more effective than generating additional written standards.

Obviously there must be a written foundation describing the processes that are to be applied in the organization, but our experiences indicated that occasionally excessive effort is put forth in developing and refining written processes. The means by which the process engineers accelerate the 'deployment' of the appropriate processes is through the activity of 'shepherding' where process and quality engineers become experts in the organization's baseline, then they provide services to the projects in explaining just how to tailor, implement, and sustain relevant processes on their projects.

In addition to the shepherding activity, the process engineers should adopt the idea of scheduling periodic (weekly on SEAS) 'Process Deployment Team' meetings where a 1-hour discussion of process implications and use is presented. All managers of the organization are invited and the process engineers lead a discussion of a process topic; for

example ‘How is the Quantitative Process Management KPA applied on a project in this domain?’ or ‘What engineering models of the environment exist for our use and how do we use them’?’

It is the responsibility of the process engineers (SEPG in CMM terminology) along with the Quality Assurance office to provide services to the project organizations by identifying appropriate assets for the projects and to help them apply these assets; without burdening the projects with undue overhead.

Recommendation 5: Measure Improvement by Product Not by Process

There is the commonly accepted belief that the quality of the software product generated is directly affected by the processes used to generate the product. For that reason, organizations implementing a process improvement program, in reality are targeting to favorably impact the end products generated by the development. They are anticipating improvement measured by product measures, ie., cost, defect rates, cycle time, accurate estimation, etc.

Although this is an obvious and simple concept, organizations occasionally overlook the importance of continually tracking the end product to verify that improvements in process are meeting the goals of improving the product. Too often, we measure success as the attainment of certain CMM levels, or ISO registration or producing more extensive processes. Measuring and tracking the product change is often overlooked. Although it is very difficult to measure trends in products over a long period of time, the exercise of establishing goals, defining measures, and capturing the starting point of these measures is valuable in itself. It provides the discipline of understanding the projects and understanding the environment through the generation of models, goals, and applied measurement.

Senior managers as well as clients often pose the challenge of proving the worth of the process improvement program. Instead of arguing that these people ‘…just don’t understand the value of process…’, the process organization must be prepared to respond to such challenges with specific measures that represent the product; not only the process. The questions are very appropriate questions and the measurement program must concentrate on continually capturing product attributes so that such questions can be addressed; even when the results may not show the expected benefits of the program.

Recommendation 6: Allocate Appropriate Resources

The activity of process improvement as well as process in general, requires effort. Although the goal is to have the process improvement activity produce a greater return on investment than the cost of the investment, the overall activity still requires a sustained effort. It is recommended that any organization identify the level of resources that it will commit to sustain the processes and process improvement program, then adhere to that commitment as it would with any project. It is a mistake to assume that this activity can be absorbed as ‘no cost’ by merely requesting that project personnel devote several hours

per week on the activity and that specific resources do not have to be allocated. From the experiences at SEAS, this approach will not adequately support the process program.

Based on nearly 8 years of experiences with varying size of organization, it was found that the typical allocation of resources for the process program was approximately 1% to 1.25% of the size of the entire organization. This effort is in addition to the specific project activities that will require additional resources. It also is recommended that the Quality Assurance activities allocate from 1.25% up to 2% of the organization that it is supporting.

Table 4-1 shows the relative cost of the process activities for different size organizations. The data is based on direct experiences of SEAS over the 8 year period.

- Requires .8% to 1.3% for process improvement activity
- Quality Assurance requires from 1% to 1.5%
- Spend 2 to 3 times more effort deploying versus writing processes

Program Size	0-20% Software	20-40% Software	40% Up
70 - 150	1.5 FTE	2.0	2.5
150 - 400	2.0 -2.5	2.5 - 4.0	3.0 - 4.5
400 - 900	3.0 - 4.0	3.5 - 4.5	4.5 - 6.0
900 - 1700	3.0 - 5.0	4.0 - 6.0	5.0 - 7.0

Table 4.1 Allocate Appropriate Resources (Based on SEAS History)

Recommendation 7: Produce 3 Specific Documents Early

There are numerous activities that must be addressed when an organization initiates a process improvement program and there are several products that also must be considered. Based on the SEAS experiences, it is recommended that 3 specific documents be produced or at least planned when the process program is established.

The 3 documents include: (1) Quality Management System (QMS) document, (2) process improvement plan, and (3) profile of the organization.

1. The QMS is a required document of ISO-9001 and has proved to be an extremely valuable handbook for SEAS as well as other organizations who have produced such a document. It has been used as an orientation guide for new employees and is a valuable reference for all personnel in characterizing the business operations of the program. It is recommended that the document capture:
   - Description of the organization and the staff (roles and responsibilities)
   - Description of the processes in place including their application.

     Standards, policies, methodologies, handbooks and general guidance.
   - Overall process planning (measurement program and process improvement program)
   - Description of how the organization complies with required benchmarks (ISO, CMM, SA-CMM, etc.)
2. The Process Improvement Plan (PIP) describes the goals, responsibilities, and approach to attaining the improvement goals. It adds the structure of a project to the activity with schedules, milestones, and most importantly- specific goals. The goals should include product as well as process goals.
3. The 'Profile' of the organization captures the general state of process usage by carrying out some type of gap analysis, but the bulk of the document should contain the product characteristics. This is the first step toward the goal of engineering software by producing quantifiable information. Sample recommended product information includes:
   - Amount of software in development and in maintenance
   - Distribution of effort across the life-cycle phases
   - Typical staffing profiles
   - Defect characteristics (number, type, severity)
   - Testing profiles
   - Maintenance costs/ per size of unit
   - Typical software cycle times (time to develop per size, time to make changes)
   - Variance in initial estimates vs. final actuals (size, cost, schedules)

Section 5 Conclusion

Over a 5-year period, the CSC SEAS Center carried out an aggressive process improvement program that resulted in an optimizing culture throughout the organization. The CMM Level 5 rating, achieved November of 1998, verified the success.

Focusing the success of the process improvement program on specific product goals, and using the compliance with industry benchmarks as a tool has helped make process improvement part of the SEAS culture. The QIP of the Software Engineering Laboratory (SEL) was used as the model for improvement and other industry benchmarks served as tools in achieving documented product goals. This paper describes aspects of the process improvement program that were key factors to the successful achievement of the CMM Level 5 rating.

The value of the investment made in process improvement was shown to be significant for the overall operations of the Center as well as the business opportunities. The quantitative value on product improvement was shown to be very difficult to determine and no conclusions could be made there.

As a result of the five years of activity, the SEAS Center produced seven recommendations that any organization should follow in implementing a process improvement program. These recommendations focus on building a culture of continuous change and improvement throughout an organization.

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